Observing geocenter motion from LEO POD using onboard GPS tracking data

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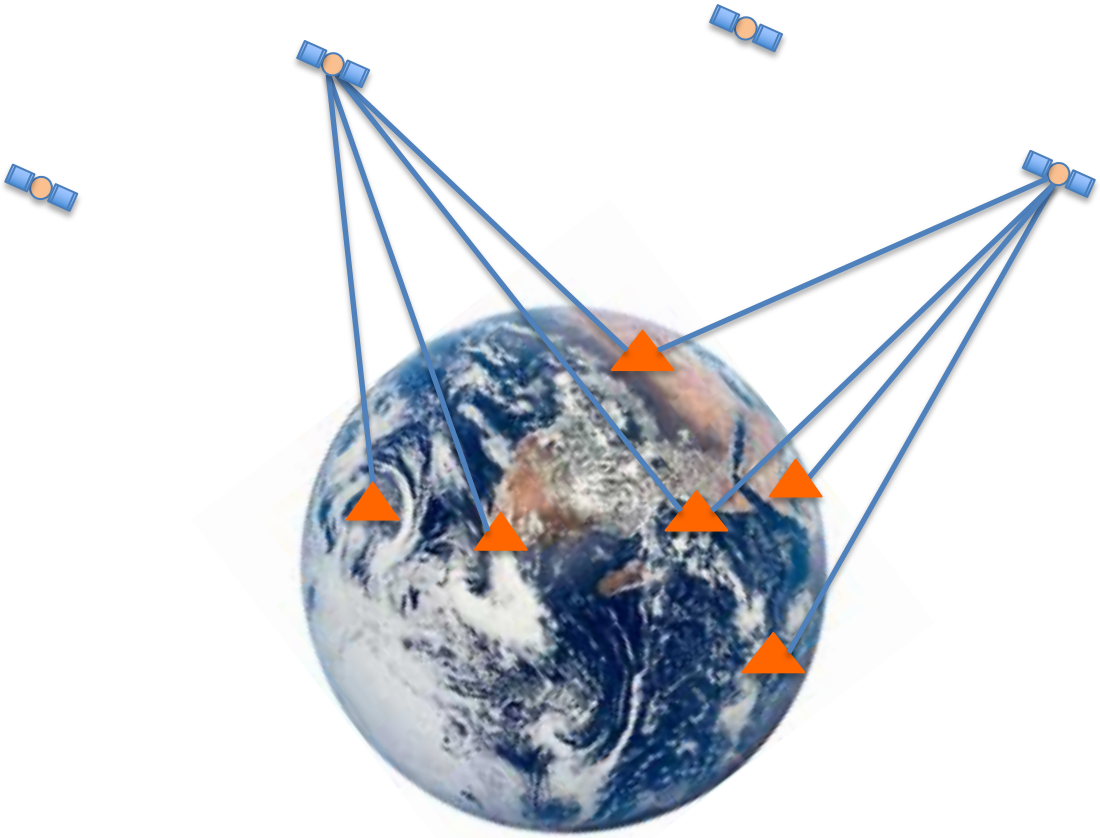
IGS Workshop 2018, October 29, 2018

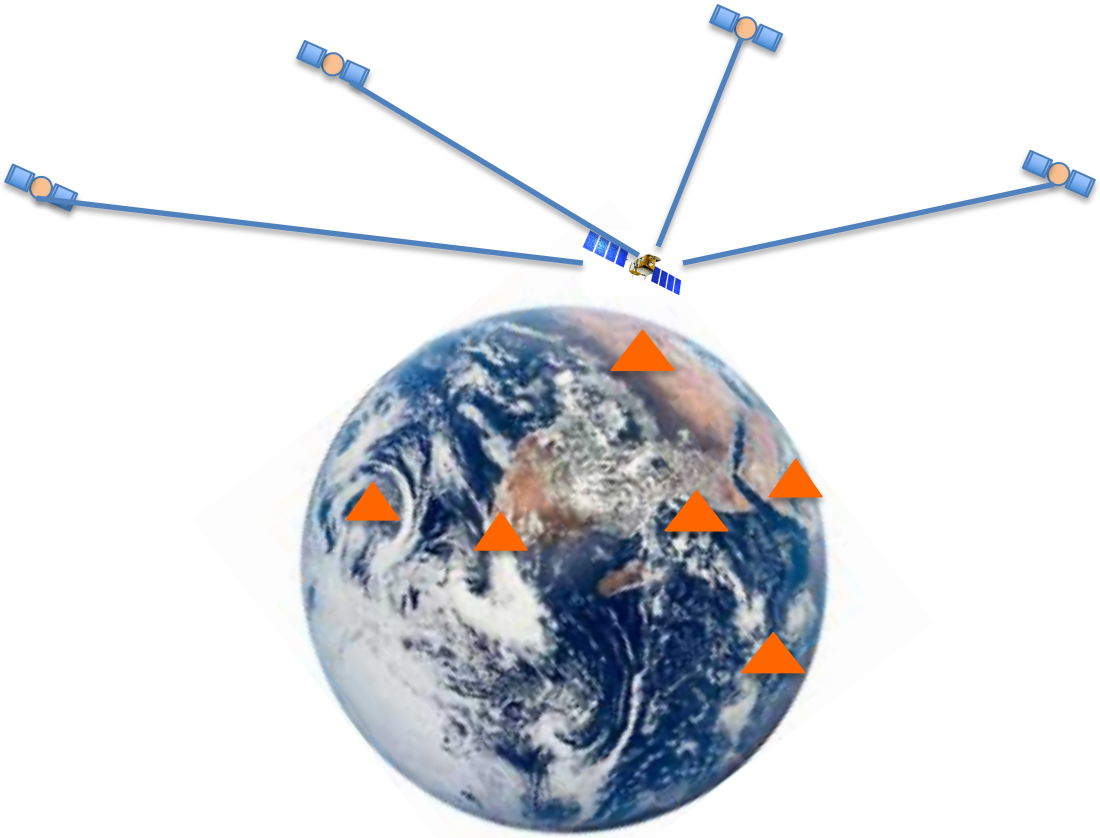
Outline

- Reference frame in LEO orbit determination
  - IGS products disseminate reference frame to users
  - JPL “fiducial” product and geocenter motion
  - Estimating geocenter motion in LEO POD
- Observed geocenter motion
  - Result from GRACE POD with accelerometer data
  - Result from other satellites without accelerometer data

Reference Frame via GPS



Reference Frame via GPS



Coordinate Systems for GPS Orbit Determination

- **Measurement tied to a ground stations, defined in a reference frame;**
- **Gravity model defined in Earth-Fixed system centered at Earth's Center of Mass (CM);**
- **Orbit integration performed in inertial coordinate system.**
- **Transformation between the Earth-Centered Inertial (ECI) system and the Earth-Centered Earth-fixed (ECEF) system is**

$$r_i = PNUXY\, r_e$$

P **– Precession;** ***N*** **– Nutation;** ***U*** **– Earth rotation;** ***X, Y*** **– Polar motion.**

JPL “Fiducial” GPS Product

- **Expressed in IGb08 reference frame, in which linear motion of geocenter is included in station coordinates definition but annual motion is not accounted for;**
- **LEO POD results using this product is also expressed in IGb08;**
- **Transformation between the Earth-Centered Inertial system and the Reference frame is**

$$r_i = PNUXY\,(r_f - \Delta r_g)$$

Δr_g – location of geocenter in the reference frame. This definition is consistent with the geocenter motion CM-CN.

In the Measurement Equation

GPS Measurements can be expressed as

$\rho = | R - r |$

***R* -- receiver position vector; *r* -- transmitter position vector.**

Both are in ECI system, transformed from the reference frame whenever necessary:

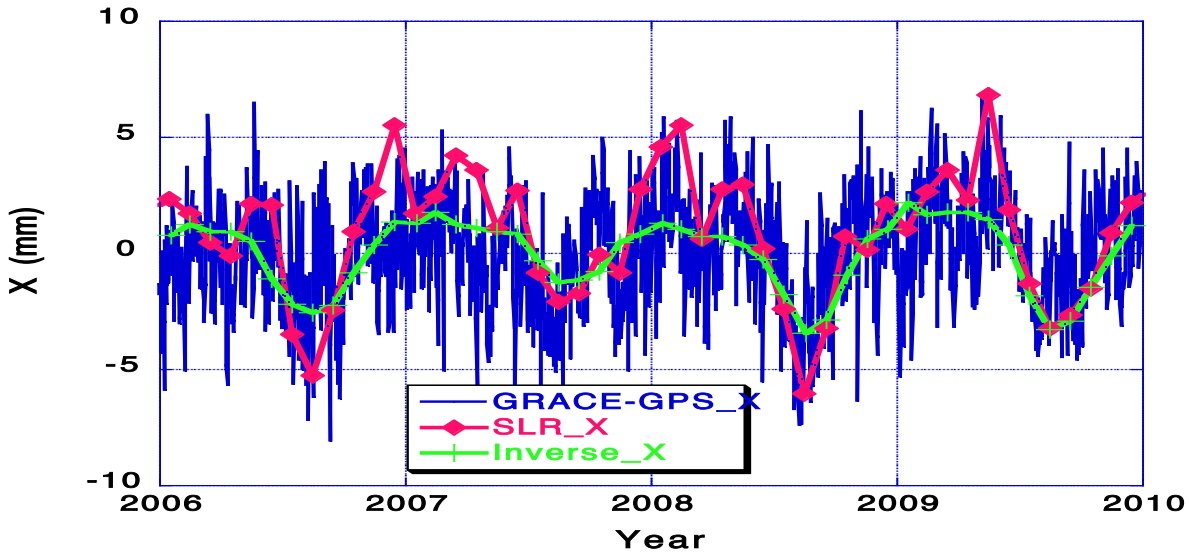
ground receiver – *R* is transformed from reference frame;

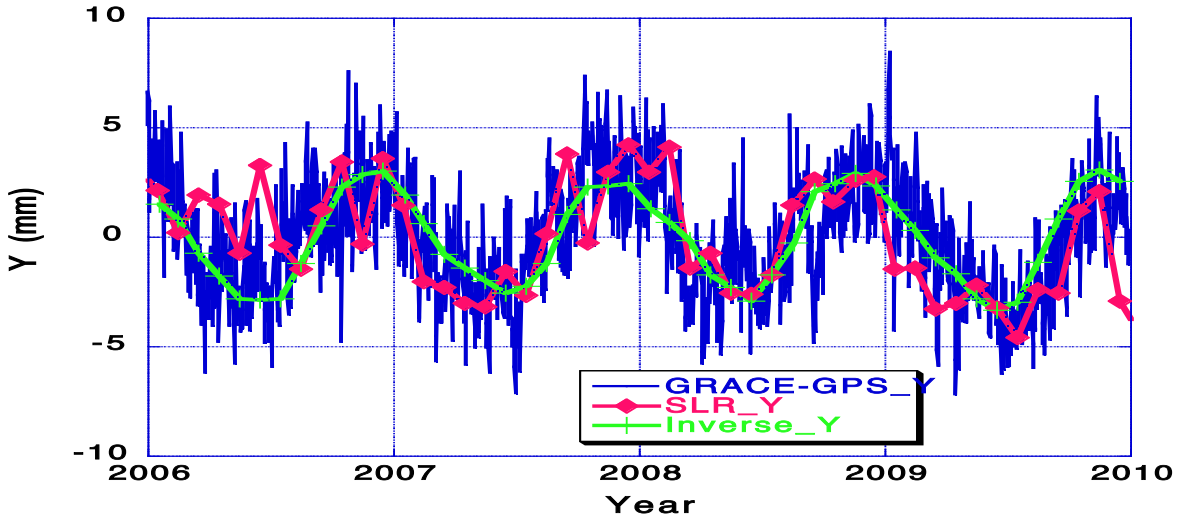
fixed GPS orbit – *r* is transformed from reference frame (of the GPS product).

Strategy for GRACE satellites POD

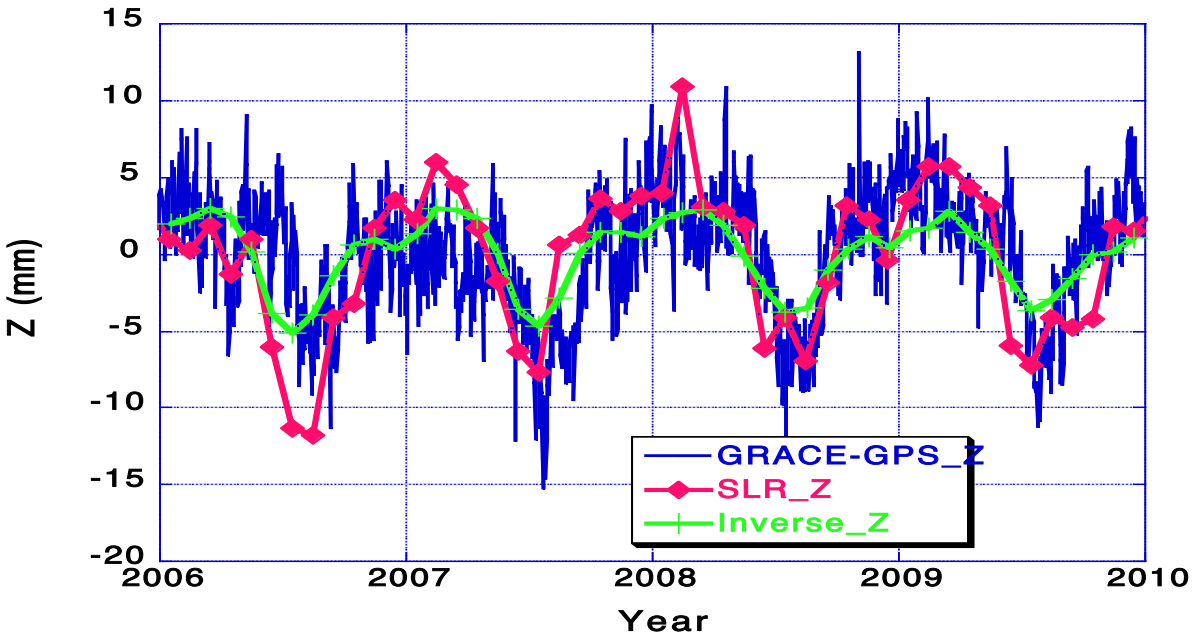
Orbit arc length: 24-hour.
Gravity model: background GIF-48 180x180, estimate 20x20.
Accelerometer data: estimate bias, bias rate and scale for each component.
GPS data: 30-second PC and LC, estimate white noise clock bias and phase bias.
Stochastic acc: estimate residual acceleration components along SRF axes.
CM location: estimate constant X, Y, and Z components in EF system, and X, Y in ECI system.

Combined solution from both GRACE satellites





Combined solution from both GRACE satellites



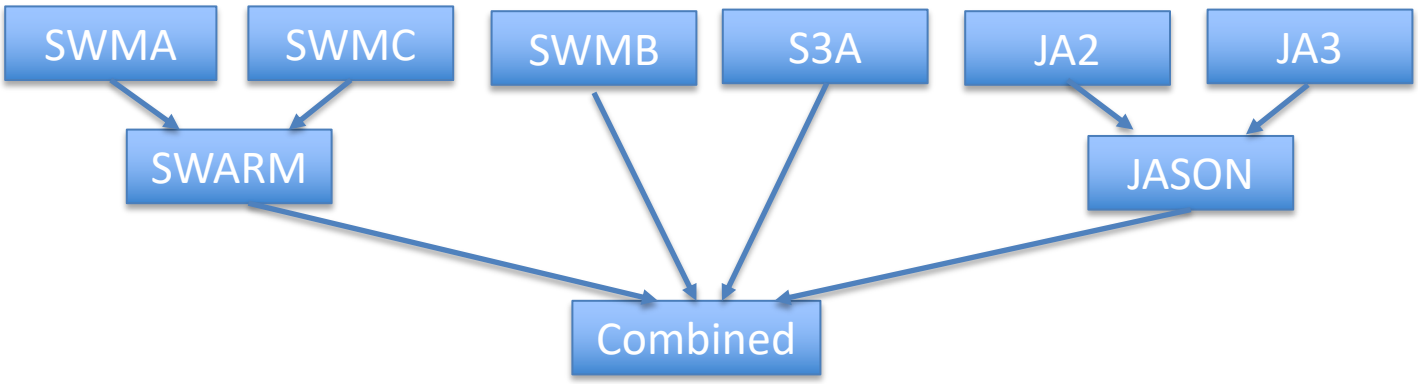
Solution	X		Y		Z	
	Amp	Phase	Amp	Phase	Amp	Phase
GRACE GPS	1.1 mm	49 day	2.7 mm	332 day	3.5 mm	35 day
CSR/SLR	2.6 mm	58 day	2.3 mm	317 day	4.7 mm	28 day
Inverse	1.9 mm	53 day	2.8 mm	333 day	2.9 mm	31 day

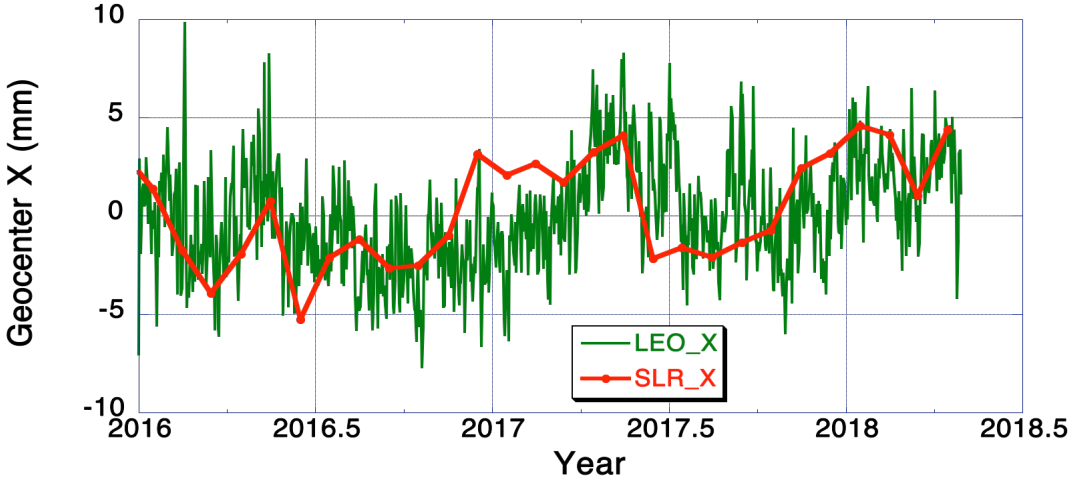
Strategy for LEOs without accelerometer

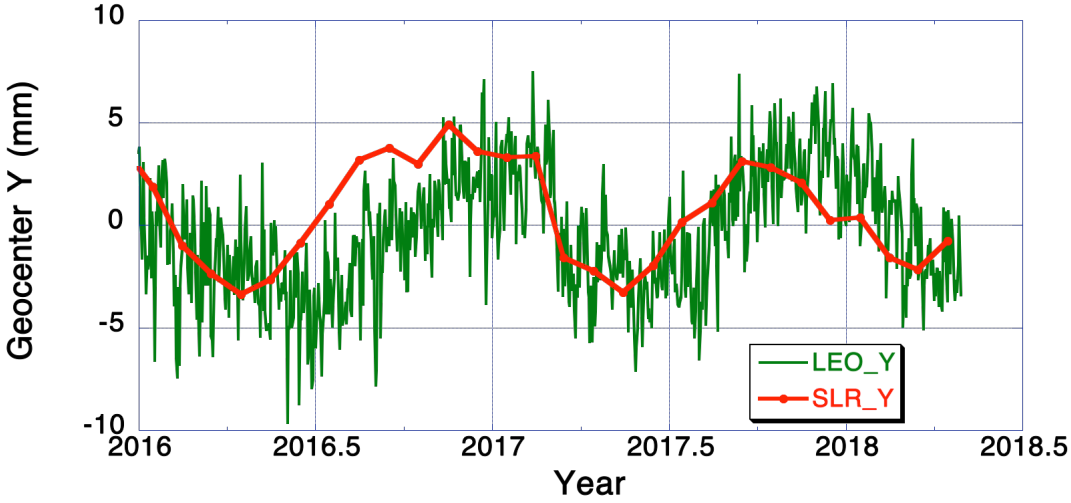
Orbit arc length: 24-hour.
Gravity model: background GIF-48 180x180, estimate 20x20.
Surface force model: estimate Cd, solar pressure scale, and once-per-revolution empirical forces
GPS data: 30-second PC and LC, estimate white noise clock bias and phase bias.
Stochastic acc: estimate residual acceleration components along orbital frame.
CM location: estimate constant X, Y, and Z components in EF system, and X, Y in ECI system.

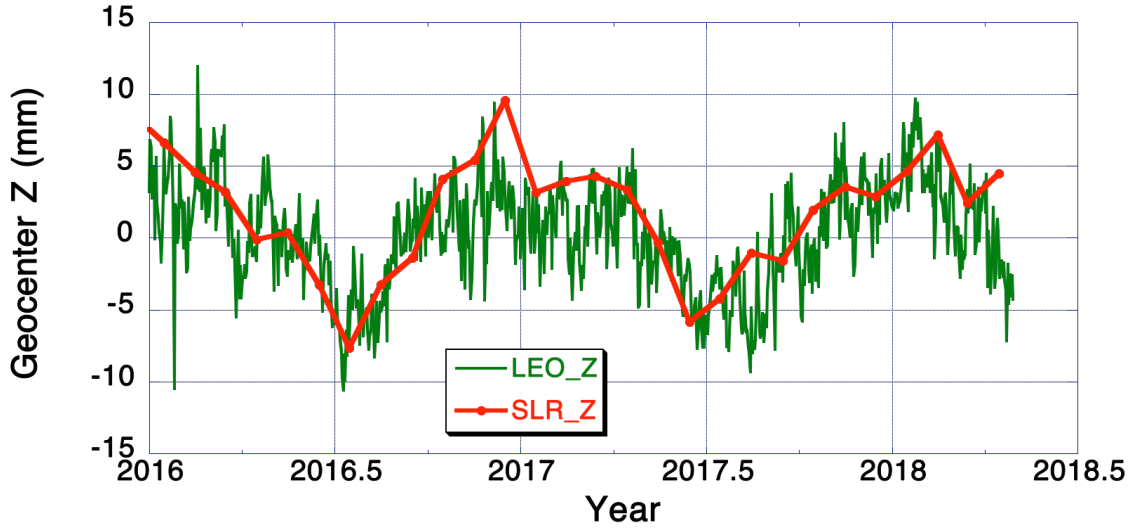
Combining solutions from individual orbits:

Solutions from 6 satellites in 4 different orbit planes are combined. Satellites in same orbital plane suffer the similar systematic errors, solutions from those satellites are combined first and treated as one solution with equivalent weight to others.

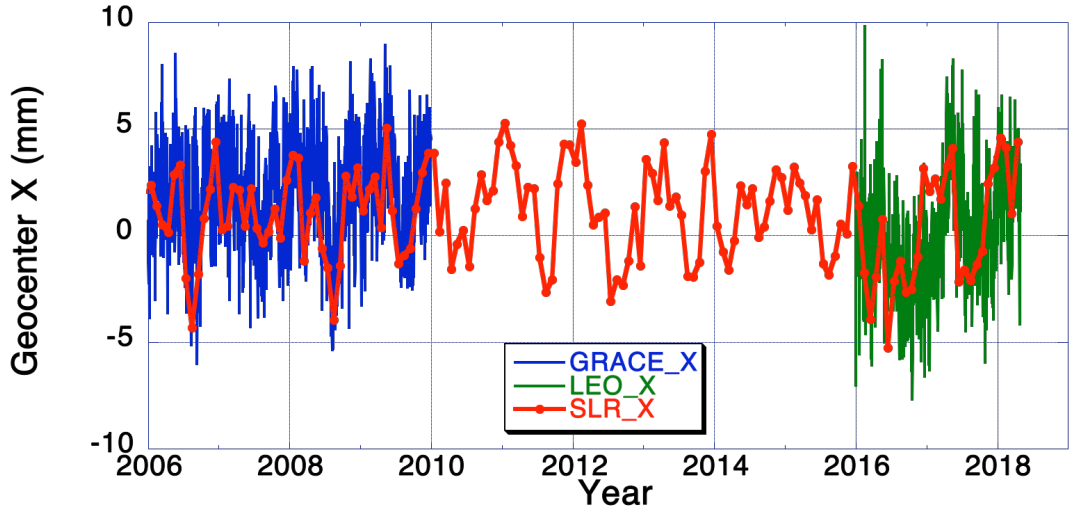


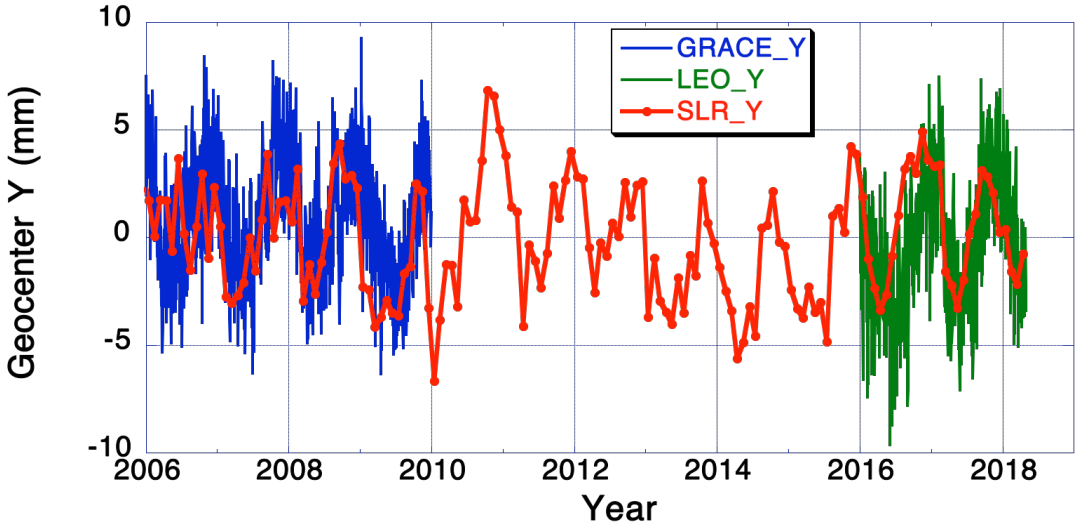

Geocenter X (mm)
10
5
0
-5
-10
2016
2016.5
2017
2017.5
2018
2018.5
Year
LEO_X
SLR_X

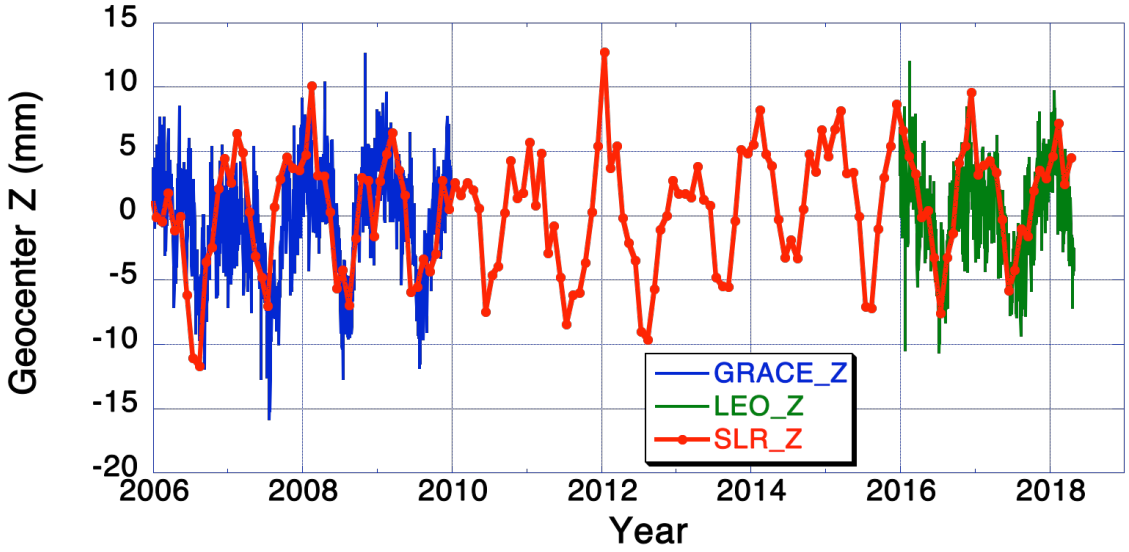

Geocenter Y (mm)
10
5
0
-5
-10
2016
2016.5
2017
2017.5
2018
2018.5
Year
LEO_Y
SLR_Y



The combined estimates agree with those estimated from SLR tracking data. They are also consistent with those estimated from GRACE-GPS and accelerometer data, as both agree with the SLR solution over time.


Geocenter X (mm)
10
5
0
-5
-10
2006
2008
2010
2012
2014
2016
2018
Year
GRACE_X
LEO_X
SLR_X


Geocenter Y (mm)
10
5
0
-5
-10
2006
2008
2010
2012
2014
2016
2018
Year
GRACE_Y
LEO_Y
SLR_Y


Geocenter Z (mm)
15
10
5
0
-5
-10
-15
-20
2006
2008
2010
2012
2014
2016
2018
Year
GRACE_Z
LEO_Z
SLR_Z

Summary

- **Earth's center of mass location in a reference frame can be determined using LEO GPS tracking data through orbit determination with GPS orbits and clocks fixed in that reference frame.**

- **Averaged from multiple satellites, solutions with or without accelerometer data are consistent, as compared to the results from SLR tracking data.**